

Claims

[c1] 1. A method for controlling engine start in a vehicle, the vehicle including an electric machine operable to provide a starting torque to the engine, and an energy storage device capable of providing energy to operate the electric machine, the method comprising:

determining a discharge power limit for the energy storage device;

determining an output power of the energy storage device;

determining an engine starting power level for the energy storage device, the engine starting power level being related to the discharge power limit for the energy storage device and an amount of output power of the energy storage device necessary to operate the electric machine to provide the starting torque to the engine;

and

starting the engine when the output power of the energy storage device is at or above the engine starting power level.

[c2] 2. The method of claim 1, the vehicle further including at least one drive wheel, the method further comprising:

operating the electric machine to provide torque to the at least one vehicle drive wheel, and wherein starting the engine includes operating the electric machine to provide torque to the engine, and wherein the engine starting power level provides an indicator of when starting the engine will reduce the torque provided by the electric machine to the at least one vehicle drive wheel.

- [c3] 3. The method of claim 1, wherein determining the engine starting power level includes defining a power level at a constant offset from the discharge power limit for the energy storage device.
- [c4] 4. The method of claim 3, wherein the constant offset is determined by measuring an output power of an energy storage device used by an electric machine when starting an engine in a vehicle under a plurality of operating conditions, thereby generating a plurality of output power measurements, and combining at least some of the output power measurements to determine the constant offset.
- [c5] 5. The method of claim 1, wherein determining the engine starting power level includes defining a power level at a variable offset from the discharge power limit for the energy storage device, the variable offset being a func-

tion of a plurality of vehicle operating conditions.

- [c6] 6. The method of claim 5, wherein the vehicle operating conditions include at least one of a coolant temperature of the engine, an altitude of the vehicle, and electrical losses of the electric machine.
- [c7] 7. The method of claim 5, wherein the function used to determine the variable offset uses static input values based on the vehicle operating conditions.
- [c8] 8. The method of claim 5, wherein the function used to determine the variable offset uses dynamic input values based on the vehicle operating conditions, the dynamic input values being based on measurements taken while the vehicle is operating.
- [c9] 9. The method of claim 1, wherein the discharge power limit for the energy storage device is at least partly based on at least one of the state of charge of the energy storage device, a temperature of the energy storage device, and an age of the energy storage device.
- [c10] 10. A method for controlling engine start in a vehicle, the vehicle including an electric machine operable to provide a starting torque to the engine, and an energy storage device capable of providing energy to operate the electric machine, the method comprising:

monitoring an output power of the energy storage device;
determining a first output power level for the energy storage device based at least in part on an amount of output power required by the electric machine to provide the starting torque for the engine; and
starting the engine when the output power of the energy storage device meets or exceeds the first output power level.

- [c11] 11. The method of claim 10, wherein the first output power level for the energy storage device is partly based on a discharge power limit for the energy storage device, the discharge power limit for the energy storage device being at least partly based on at least one of the state of charge of the energy storage device, a temperature of the energy storage device, and an age of the energy storage device.
- [c12] 12. The method of claim 11, wherein the first output power level for the energy storage device is set at a constant distance from the discharge power limit for the energy storage device.
- [c13] 13. The method of claim 11, wherein the first output power level for the energy storage device is set at a variable distance from the discharge power limit for the en-

ergy storage device, the variable distance being a function of a plurality of vehicle operating conditions.

- [c14] 14. The method of claim 13, wherein the vehicle operating conditions include at least one of a coolant temperature of the engine, an altitude of the vehicle, and electrical losses of the electric machine.
- [c15] 15. The method of claim 13, wherein the function used to determine the variable distance uses static input values based on the vehicle operating conditions.
- [c16] 16. The method of claim 13, wherein the function used to determine the variable distance uses dynamic input values based on the vehicle operating conditions, the dynamic input values being based on measurements taken while the vehicle is operating.
- [c17] 17. A vehicle, comprising:
 - an engine;
 - an electric machine operable to drive the vehicle and to provide a starting torque to the engine;
 - an energy storage device capable of providing energy to operate the electric machine; and
 - at least one controller configured to determine a discharge power limit for the energy storage device and an output power of the energy storage device, the at least

one controller being further configured to determine an engine starting power level for the energy storage device and start the engine when the output power of the energy storage device is at or above the engine starting power level, the engine starting power level being related to the discharge power limit for the energy storage device and an amount of output power of the energy storage device necessary to operate the electric machine to provide the starting torque to the engine.

- [c18] 18. The vehicle of claim 17, wherein a constant starting power value is preprogrammed into the at least one controller, and the at least one controller defines the engine starting power level as a difference between the discharge power limit for the energy storage device and the constant starting power value.
- [c19] 19. The vehicle of claim 17, wherein the at least one controller determines the engine starting power level for the energy storage device by implementing a function that uses inputs based on a plurality of vehicle operating conditions.
- [c20] 20. The vehicle of claim 19, wherein the vehicle operating conditions include at least one of a coolant temperature of the engine, an altitude of the vehicle, and electrical losses of the electric machine.

- [c21] 21. The vehicle of claim 19, wherein the inputs used by the function are static values based on the vehicle operating conditions.
- [c22] 22. The vehicle of claim 19, wherein the inputs used by the function are dynamic values based on the vehicle operating conditions, the dynamic values being based on measurements taken while the vehicle is operating.